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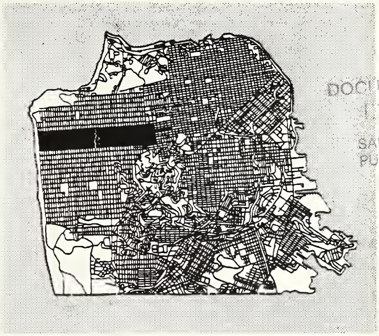
GOLDEN GATE PARK MASTER PLAN



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BACKGROUND REPORT

Geology, Groundwater, and Recycled Water

SAN FRANCISCO RECREATION AND PARK DEPARTMENT

Prepared By:
GEO RESOURCE CONSULTANTS

MARCH 1993

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GOLDEN GATE PARK MASTER PLAN

GOLDEN GATE PARK

SAN FRANCISCO, CALIFORNIA

PREPARED FOR:

ROYSTON, HANAMOTO, ALLEY, & ABEY
225 MILLER AVENUE
MILL VALLEY, CALIFORNIA 94942-0937

PREPARED BY:

GEO/RESOURCE CONSULTANTS, INC.
505 BEACH STREET
SAN FRANCISCO, CALIFORNIA 94133

FEBRUARY 22, 1993

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EXECUTIVE SUMMARY

Geology

Golden Gate Park (GGP) is located within the Coast Ranges geologic province which is characterized by a northwest trending series of ranges and valleys. The Park is underlain primarily by Holocene eolian dune sands with some localized areas of artificial fill. These surficial deposits are underlain by the Colma Formation. The Colma Formation ranges up to 400 feet thick below the Park and consists of unconsolidated sand and silty sand with scattered clay beds. Exposures of the Franciscan Complex basement rocks crop out in some central and eastern areas of the park. A particularly noteworthy outcrop is Strawberry Hill, which consists of a melange of sandstone, greenstone, chert, and shale of the Franciscan Complex.

GGP is located within a seismically active region. Active faults which have generated moderate to strong earthquakes within the Bay Aréa include the San Andreas, the Seal Cove - San Gregorio, Hayward, Calaveras, Rogers Creek, Green Valley, Concord and the Greenville faults. A major earthquake on the San Andreas, Seal Cove - San Gregorio, Hayward, or Calaveras faults could potentially cause strong to severe ground shaking at GGP. The strongest earthquake in the Bay Area during historic time was the 1906 earthquake on the San Andreas fault which was estimated to be approximately 8.3 on the Richter scale. Significant damage to various buildings within GGP were reported. The only fault that runs through GGP is the City College fault, which is not considered active by the California Division of Mines and Geology (CDMG).

and manual controls. Some portions of the park require irrigation at night, which is supplied by overflow from Stow Lake. Irrigation system operations need to be fully understood prior to designing new or upgraded systems. A new reservoir may be required if well water were to be substantially increased.

All of the water impoundments at GGP are artificial and are supplied by well water. Many of the lakes are currently leaking substantial amounts of water.

Recycled Water

A Water Recycling Master Plan has recently been prepared by James M. Montgomery Consulting Engineers for the City and County of San Francisco. The Master Plan outlines methods to provide recycled water to potential users, one of which would be GGP for irrigation water. For GGP, recycled water would be produced at the future Oceanside Water Pollution Control Plant (OWPCP). Regulatory requirements state that recycled water use for irrigation in areas of high public exposure (which would be the case at GGP) require tertiary treatment.

An evaluation of the predicted quality of recycled water from the OWPCP suggests that water quality constituents would be within the acceptable or marginal levels for irrigation although distribution by sprinkler irrigation could aggravate the impact of salts on various types of vegetation. Conversations with Park personnel indicate that there is concern regarding impacts to certain types of vegetation from recycled water use. Bench tests using recycled water and recycled water blended with groundwater could be conducted on various vegetation to assess potential impacts prior to modifying the existing system to irrigate with recycled water.

Recycled water could be transported to GGP either through the existing AWSS system or through new piping systems. Storage for recycled water could be maintained at existing reservoirs currently used to store groundwater, and potentially, new reservoir sites. Storage in existing lakes would probably result in excessive eutrophication and could result in clogging of irrigation lines by algae.

1.0 INTRODUCTION

The current use of Golden Gate Park (GGP) is an urban park and recreation area for the City of San Francisco. Most of the park is open space with a limited number of structures and roadways. There are 10 lakes in GGP with a combined surface area of approximately 31 acres (USGS, 1990).

Golden Gate Park, located in the western part of San Francisco, is approximately 1,017 acres in size. The park sits upon old migratory sand dunes which were planted with vegetation and stabilized during the early 1900s. Topography slopes gently to the west falling from approximately 330 feet above sea level in the northeast corner of GGP near the Horseshoe Courts to approximately 17 feet above sea level in the northwest portion of GGP near the intersection of the Great Highway and Kennedy Drive. Slopes in GGP average approximately 30 to 50 feet in height and are generally gentle to moderately steep.

2.0 GEOLOGIC SETTING

2.1 Regional Geology

Golden Gate Park is located near the northern tip of the San Francisco Peninsula, within the California Coast Ranges geologic province. The Coast Ranges are a northwest trending series of ranges and valleys. Basement rocks throughout most of the province are composed of rocks of the late Jurassic Franciscan Complex, a melange of sedimentary, volcanic, and metamorphic rocks. West of the San Andreas fault zone, basement rocks consists of Cretaceous-age granitic rocks and older metamorphic rocks of the Salinian block. Tertiary-age sedimentary and volcanic rocks overlie basement rocks throughout much of the area.

The Coast Ranges province was formed by tectonic deformation that occurred episodically in the region since the late Cretaceous. Deformation was largely compressional until the Miocene Epoch, when large strike-slip faults developed in the region. A number of these strike-slip faults remain active as the region continues to be tectonically deformed.

San Francisco Bay is a partially flooded structural depression within the Coast Ranges. The relatively deep Bay trough was formed by tectonic movements during the Quaternary period. The basin is roughly bounded by the Hayward fault zone to the east and the San Andreas fault zone to the west. Partial in-filling of the basin by alluvial and estuarine sediments has taken place during Quaternary time.

2.2 Site Geology

GGP occupies approximately 1017 acres in western San Francisco. Surficial deposits at GGP consist primarily Holocene eolian dune sand deposits with some areas of artificial fill. Please refer to Figure 2-1, Geologic Map of Golden Gate Park. The dune sands, which cover most of the park, are generally clean, light gray, fine- to medium-grained, and well-sorted (Schlocker, 1974). In addition, the dune sands are loose and may be easily excavated. The park and the general vicinity was the site of active sand dune fields until the urbanization of San Francisco in the mid-nineteenth century. The dune sand deposits vary in thickness and may be as much as 80 feet deep (USGS, 1990).

Artificial fill, which may have been used to fill ravines or depressions and create berms during the course of GGP and roadway development, is present at various locations throughout the park. The artificial fill generally consists of dune sand but may contain silt, clay rock waste, man-made debris, and organic waste (Schlocker, 1974).

The Colma Formation, which does not crop out in GGP, underlies the dune sand and artificial fill deposits. Figure 2-2 shows a generalized cross section across GGP. The formation generally consists of unconsolidated, moderately well sorted, fine- to medium-grained sand and silty sand with occasional clay beds 6 inches to 5 feet thick (Schlocker, 1974). The sands, commonly light brown to orange in color, are thought to be water-laid (Schlocker, 1974). The Colma Formation ranges up to approximately 400 feet thick in GGP (Draft USGS, 1992).

Scattered outcrops of the Franciscan Complex are present in the central and eastern portion of the park (Schlocker, 1974). One of the most significant of these outcrops is Strawberry Hill. Geologist A.C. Lawson described Strawberry Hill as "a chert knob rising abruptly in the sand wastes" (Lawson, 1908). Detailed mapping by Schlocker indicates that Strawberry Hill consists of sandstone, greenstone, chert, and shale of the Franciscan Complex overlain in some areas by dune sand, slope deposits, and artificial fill (Schlocker, 1974).

Sandstone of the Franciscan Complex is generally thickly-bedded and massive graywacke interbedded with thin layers of shale and fine-grained sandstone (Schlocker, 1974). When fresh, the sandstone is hard and medium-gray in color. Deeply weathered sandstone is pale orange, friable and crumbles under finger pressure (Schlocker, 1974). Greenstone of the Franciscan Complex consists of aphanitic (fine-grained) to medium-grained altered volcanic rock. This includes flows, dikes, sills, plugs, agglomerate, tuff, and pillow lavas (Schlocker, 1974). Chert of the Franciscan Complex is generally found in layers 1 to 5 inches thick alternating with shale. The chert, which can also be found in massive, unbedded bodies, is generally grayish red, hard, brittle, and fractured. The shale layers are brittle and crumbly (Schlocker, 1974).

2.3 Seismicity

GGP is located within a seismically active region, which has experienced a number of strong earthquakes during the 200-year period for which historical records exist. A number of active faults which have generated moderate to strong earthquakes are located in the San Francisco Bay Area. These include the San Andreas fault, Seal Cove - San Gregorio, Hayward fault, Calaveras fault, Rodgers Creek, Green Valley, Concord, and the Greenville fault. Figure 2-3 identifies major active/potentially active faults within the San Francisco Bay Area. Table 2-1 lists these active faults, the maximum credible earthquake which may be reasonably anticipated, the maximum acceleration of bedrock beneath GGP which may accompany such an earthquake, and the relative distances of the faults from GGP.

A major earthquake on the San Andreas, Seal Cove - San Gregorio, Hayward, or Calaveras faults could potentially cause strong to severe ground shaking at GGP while earthquakes on either the Rodgers Creek, Concord fault or other faults could produce moderate to strong ground shaking.

The strongest earthquake in the Bay Area during historic time was the 1906 earthquake on the San Andreas fault. This earthquake registered approximately magnitude 8.3 on the Richter scale. A State Earthquake Investigation Commission report, prepared by A.C. Lawson in 1908, reported evidence of significant damage within GGP. Descriptions of the damage included: brick and plaster walls at the Museum in the Park, located not far from the corner of Eleventh Avenue and Fulton Street, were cracked very badly and considerable portions fell; considerable brick and stone fell from the cornice of the music stand near the museum; the restaurant at the children's playground in the GGP was "wrecked"; and the circular 2-story concrete observatory at the top of Strawberry Hill was "utterly ruined by the shock" (Lawson, 1908). In addition, Lawson noted that the all of the driveways in the western portion of GGP showed scattered narrow fissures. Lawson added that "there were but few structures here, and they did not show significant damage ... these were low, strong, frame buildings" (Lawson, 1908).

The inferred trace of the City College fault, as shown on the geologic map, runs approximately north to northwest through the western portion of the park (USGS, 1990). The fault, which occupies a band about 0.5 to 1 mile wide, separates Franciscan Complex basement rocks on the northeast from the Great Valley sequence basement rocks on the southwest (USGS, 1990). This fault is not considered to be active by the California Division of Mines and Geology (CDMG). Faults are considered active based either on historical fault rupture or on geologic evidence that clearly demonstrates fault rupture during Holocene time (approximately within the last 10,000 years before present).

The San Bruno fault, a northwesterly trending fault, is located approximately 2 miles south of Golden Gate Park. The age, exact location, and the offset of the San Bruno fault in the Lake Merced area is not known (USGS, 1990). The San Bruno fault is not considered to be active by the CDMG.

3.0 GROUNDWATER CONDITIONS

3.1 The Westside Groundwater Basin

The Westside Groundwater Basin underlies much of the western part of San Francisco, including Golden Gate Park. It is the city's largest groundwater basin and is not fully contained within San Francisco. The basin is approximately 2 miles wide and extends southward from Lincoln Park about 6 miles along the coast to Daly City and from there southeastward an additional 5 miles to the San Francisco Bay near San Bruno (USGS, 1990).

The Westside Basin is comprised of unconsolidated sediments overlying bedrock. The unconsolidated sediments, or aquifer materials, generally consist of dune sands and the underlying Colma and Merced Formations. In the GGP area, the Franciscan Complex and the Great Valley Sequence (bedrock) are overlain by the Colma Formation, which in turn is overlain by the dune sands (USGS, 1990). Groundwater is generally not available from the hard, fractured bedrock.

The Colma Formation consists of fine-grained sand and silty sand with occasional beds of clay as much as five feet thick. The thickness of the Colma Formation ranges up to approximately to 400 feet in GGP (Draft USGS, 1992).

Holocene eolian dune sands cover most parts of the groundwater basin north of Lake Merced. The dune sands consist of well-sorted, fine- to medium-grained sand approximately as much as 80 feet thick in GGP (USGS, 1990).

Figure 2-2 shows a generalized cross section across GGP.

Aquifer testing conducted in the Westside Basin indicate relatively high permeabilities and groundwater flow rates. Because the Westside Basin is a single groundwater basin, pumping or recharge in one area can affect water levels in other areas.

The GGP area historically has not suffered any reported seawater intrusion. The exact reason for this is unknown, but it is believed that sufficient groundwater recharge keeps groundwater levels above sea level (Yates, personal communication, June, 1992).

3.2 Aquifer Thickness

Recent information the thickness of alluvium across GGP is available from geophysical surveys performed by the USGS (Draft, 1992; See Figure 3-1). A hydrogeologic cross section depicts the saturated thickness of alluvium across GGP in an east-west direction (See Figure 3-2). These data indicate that the alluvial basin beneath GGP ranges from less then 100 feet to approximately 400 feet thick, and that the basin appears to be thinnest north to northeast of the Arboretum where a buried bedrock high exists. The basin is deeper in the western half of GGP with an average approximate depth of 350 feet. The Elk Glen well, located in the central portion of the park, is known to reach a depth of 370 feet and, apparently, did not encounter bedrock (Woodward-Clyde Consultants, 1982).

3.3 Water Quality

Groundwater quality in GGP is discussed by the USGS in relation to sources of recharge to the basin (USGS, 1990). Recharge of the Westside Basin is primarily from rainfall, irrigation return-flow, and groundwater inflow from adjacent basins, and to a lesser extent, leaking water and sewer pipes (Geo/Resource

Consultants, 1991). In the western part of San Francisco, sewer lines are generally above the water table which promotes leakage of sewage (USGS, 1990).

Based on the mineral chemical analysis for all of the GGP wells, except Arboretum No. 4, the USGS concluded that groundwater in GGP tends to have a composition resulting from the mixing of rainfall, irrigation-return flow, and leaking water and sewer pipes. Results of the USGS mineral chemical analysis are included in Table 3-1. Groundwater quality also is affected by chemical interaction with sediments in the aquifer system (USGS, 1990). The USGS found that except for high nitrate concentrations in some wells, groundwater is generally of good quality. The most likely sources of nitrate are seepage from sewers and irrigation return flow (USGS, 1990).

4.0 WATER SUPPLY FOR IRRIGATION

GGP irrigation water consists of approximately two-thirds well water and one-third City water. Although annual water use has not been systematically recorded by SFRPD, measurements made by the USGS, City utility records, and projections of water use presented in the Recycled Water Master Plan, are used in this Section to estimate water usage in GGP. Potential increases in groundwater production are also assessed in this Section in relation to park hydrogeology and the existing water supply distribution system.

4.1 Golden Gate Park Wells

Groundwater is pumped from seven operating wells located in GGP to supply water for irrigation. Figure 3-1 shows the locations of the wells and associated reservoirs. In general, the GGP wells are pumped up to 8 hours per day, 5 days per week during the summer months and sporadically when needed during the remainder of the year (Geo/Resource Consultants, 1991). Wells that are active within GGP include two wells near the north windmill (North Mill West and North Mill East), one well near the south windmill (South Mill), Elk Glen well near Elk Glen Lake, Arboretum No. 4 and No. 5 wells in the Arboretum, and the Alvord well in the east end of the park (Geo/Resource Consultants, 1991).

In a drought response and groundwater assessment for GGP, prepared by Geo/Resource Consultants, Inc. (GRC) in 1991, the general condition of the GGP wells and pumps was evaluated by JMM personnel. Evaluations included physical examinations, record review, and recommendations concerning each well in GGP. The general condition of the wells and pumps in GGP were found to be typical of units that do not have a monitoring or preventative maintenance program (GRC, 1991). JMM observed that the pumps are mostly dependable and continue to operate at a relatively steady basis, however, there appear to be some system problems. Some of these problems include the North Mill West and Alvord wells breaking suction and pumping a combination of air and water, and the South Mill well pumping sand (GRC, 1991). At the time of the report, the Elk Glen well pump had failed and required replacement. The pump has since been replaced and the well is currently operating.

4.2 Irrigation Water Supply Estimates

The quantity of groundwater used in GGP has been estimated using several direct and indirect methods. Irrigation rates were calculated by the USGS using a soil-moisture algorithm. This method indicated that a total of 1,700 acre-feet (1.5 mgd) was used for irrigation in 1988. To substantiate empirical estimates, measurements of monthly pumpage of wells was added to City water usage records (USGS, data files, 1990). Well pumpage was measured by the USGS using hour meters installed at the wells for a few summer months in 1988 and for the entire year of 1989 (See Table 4-1).

City water consumption data at SFWD irrigation service connections for GGP were only available for 1988 (See Table 4-2; USGS data files, 1990). Consumption was estimated by adding the billing units used (1 billing unit equals 100 cubic feet, or 748 gallons) at each SFWD service connection that supplies irrigation water to GGP. This method indicated that 363 acre-feet (an annual average of 0.3 mgd) City water was used in GGP for irrigation.

As rainfall was very similar during 1988 and 1989 (14 inches and 15 inches, respectively), irrigation trends were likely to be similar between the two years. Thus, pumpage data for 1989 and City water consumption data for 1988 were added to estimate the amount of water used annually for irrigation at GGP during the 1988-1989 time interval.

Tables 4-1 and 4-2 show that pumpage at GGP in 1989 equalled 1363 acre-feet (1.2 mgd) and City water was measured at 363 acre-feet (0.3 mgd). Thus, total annual irrigation is estimated at 1,726 acre-feet (1.54 mgd) using direct measurement techniques. This compares well with the value estimated (1,700 acre-feet) using the soil-moisture algorithm.

Table 4-1 shows that the Elk Glen well supplied the highest quantity of water at 979 acre-feet (0.9 mgd). The Alvord well produced the second highest quantity of water, 104 acre-feet (0.09 mgd). Although the Alvord well is not known for its high yield in comparison to the wells in the western part of the park, the greater need for water on the east necessitates the relatively intensive use of this lower yield well. The lowest amount of water, 10.5 acre-feet (0.009 mgd), was pumped from Arboretum No. 5.

4.3 Other Water Consumption Estimates

Using well water and City water consumption data, an average of 1.5 mgd is used at GGP for irrigation. This figure is lower than the irrigation consumption figure estimated by JMM using peaking factors and irrigation loading rates calibrated for 1987 (JMM, October 1992). Peaking factors were used from City irrigation consumption records to define the relationship between the peak water-use month and average annual irrigation demand. Then, to estimate average annual irrigation demand in areas not serviced by City water, the peaking factor was divided into peak month irrigation that was estimated from evapotranspiration data (irrigation loading rate). Using this method, GGP irrigation water consumption was estimated at 1.75 mgd or 1959 acre-feet per year (JMM, October, 1992). The reason for the discrepancy between USGS estimates and JMM estimates is not known.

4.4 Potential Increase in Well Productivity

Based on historic water level information, the USGS concluded that groundwater could be further developed in the GGP area (USGS, 1990). They estimate that between Lincoln Park and the northern boundary of the Lake Merced area, the calculated outflow to the ocean is approximately 4,000 acre-feet/year (3.5 mgd). The USGS suggests that some of this outflow could be captured but wells would have to be carefully designed to avoid seawater intrusion and potential subsidence. Additionally, the overall depth and extent of the groundwater basin, accompanied by relatively high water levels, suggests that water storage is signficant within the basin and can be further developed (See Figures 3-1 and 3-2. Groundwater development, however, should be accompanied by careful monitoring to prevent overdraft conditions and/or seawater intrusion.

Based on a preliminary USGS water basin budget for GGP, GRC identified and evaluated two scenarios to increase groundwater yield at the park. The first was to increase the pumping schedule at existing wells, specifically the South Mill well, and the second was to install a new well(s) in the general vicinity of the Buffalo Paddock and/or the Big Recreation Ball Field, near the Arboretum (GRC, 1991). The proposed new well locations are shown on Figures 3-1 and 4-1.

Based on hydrogeologic conditions, and the performance and condition of the wells, GRC concluded that increased withdrawal through a longer schedule may be effective at the South Mill well. The Elk Glen well could also be a candidate for increased well production, however, because it was inoperable at the time of the report, was not evaluated. The GRC report indicated that potential problems associated with increasing production at the South Mill well could include seawater intrusion due to the close proximity of the ocean, sand production, and poor pump efficiency (GRC, 1991). However, Mr. Lloyd Pool (the retired head plumber at GGP) indicated that well production from the Elk Glen well was replaced by increased pumpage at the South Mill well and that seawater intrusion did not appear to occur (Personal communication, November 25, 1992).

GRC reported that a significant increase in the pumping schedule (to 12 hours/day for 6 months) at the South Mill well would result in an increase of 415 acre-feet/year (0.4 mgd) over the total GGP pumpage of 0.6 mgd during the 1988 water year. This amount could replace City water usage of 0.3 mgd.

GRC noted that hydrologically, the western portion of the park is the most suitable for development and recommended the general vicinity of the Buffalo Paddock as a proposed location for a new well. Estimated pumpage from this new well would result in an increase of approximately 604 acre-feet/year (0.5 MGD) over the 1988 water year (GRC, 1991). This amount could also replace City water usage of 0.3 mgd.

During the preparation of the drought response and groundwater assessment for GGP, San Francisco Recreation and Park Department (SFRPD) personnel expressed a desire to install a new well in the eastern portion of the park, where water needs are higher. GRC concluded that hydrogeologic conditions may be suitable at the Big Recreation Ball Field, near the Arboretum; however, GRC noted that the production is not expected to be as high at the proposed well site as at the Buffalo Paddock. Estimated pumpage from this new well would result in an increase of approximately 202 acre-feet/year (0.2 MGD) over the 1988 water year (GRC, 1991). This amount of water does not quite meet City water usage of 0.3 mgd.

4.5 Current Water Supply Distribution

Water supply distribution in GGP for irrigation and for maintaining water impoundments occurs through a series of 8 to 10-inch lines which branch off into smaller lines throughout the park. The most recent map showing irrigation lines is dated 1965 and, according the SFRPD personnel, does not accurately reflect the current distribution system. In an attempt to update the map, the SFDPW held an informal meeting on November 25, 1992 with Mr. Lloyd Pool, the previous head plumber at GGP, to better understand the current distribution system. Figure 4-1 shows a version of the 1965 map with draft revisions obtained at the November 25 meeting. The map primarily shows the larger water supply and irrigation lines and the areas that are serviced by well water and by City water.

Currently, reservoirs and booster pump stations exist adjacent the North Mill wells and at the Arboretum. The North Mill wells service the western portion of the park. The Arboretum well water is stored at the Waterworks pumping plant reservoir and services the eastern portion of the park. The Elk Glen Lake serves as a reservoir for the Elk Glen well, which supplies the reservoir on top of Strawberry Hill and Stow Lake. The Alvord well is linked directly into the eastside irrigation system. Water from the South Mill well is directly linked from a booster station to the irrigation lines that serve the western portion of the park.

Irrigation is controlled primarily by visual observation and manual controls. Stow Lake is filled from overflow occurring at the reservoir at the top of Strawberry Hill. GGP gardeners are required to drive by Stow Lake periodically and regulate the overflow to Stow Lake manually. Mr. Pool indicated that a sensor should be installed in Stow Lake to automatically control overflow.

Some portions of the park require irrigation at night, specifically, the buffalo paddock and golf course. This is currently conducted by allowing Stow Lake water to flow, by gravity, back down the irrigation lines that supply well water from the North Mill wells to the western portion of the park during the day. This method of night irrigation can only be conducted if the wells are not pumping. Apparently, when the wells are turned off, a check valve opens automatically to allow Stow Lake water to flow back down the lines. It is uncertain whether night irrigation could be serviced by wells pumping at night or whether some unavoidable overflow from the Stow Lake is being distributed at night.

All of the water impoundments at GGP are artificial and are supplied by well water. To prevent subsurface seepage into underlying sands, the water impoundments have been lined with crushed red rock or relatively impermeable clay. The Fly Fishing Pond and reservoirs are lined with concrete. Many of the lakes have experienced significant leakage through the liners which are in disrepair. Leakage has been reported in North Lake and Lloyd Lake (USGS, 1990). In general, all of the lakes leak with the exception of Mallord and Metson Lakes (Personal communication, Mr. Mark Siegenthaler, SFRPD, December 4, 1992).

Previously, the quantity of water obtained from the Arboretum wells to supply the Waterworks reservoir and thus, the eastern portion of the park, was inadequate. To supplement the wells, a 12-inch line designed to distribute Waterworks reservoir water to Stow Lake was valved so that overflow from Stow Lake could supplement the Waterworks reservoir.

4.6 Potential Increase in Groundwater Supply

In order to increase groundwater supply at GGP, new reservoir capacity would be required in addition to installing new distribution lines or modifications of existing lines. Mr. Pool indicated that two reservoir sites have been considered: 1) an increase or addition to the reservoir adjacent to the North Mill wells, or 2) the installation of buried water tanks at South Mill and/or north of McLaren Lodge (Personal communication, Ms. Deborah Learner, March 8, 1993). At either location, irrigation lines that currently deliver City water could be used to deliver well water and some new lines would be installed to enhance irrigation capabilities.

5.0 RECYCLED WATER USE

This section discusses the potential for using recycled water for irrigation at GGP in terms of regulatory requirements, historic experiences with recycled water use, and potential impacts on existing vegetation and land use.

5.1 Background

Recycled water use at Golden Gate Park dates back to the early 1900s when 1,017 acres of "great sand waste" was transformed into a garden spot through the application of raw sewage and ground water (JMM, 1992). In 1932, the McQueen Water Treatment Plant, designed to produce secondary treated water, was constructed in GGP. Initially, recycled water was used to irrigate the western portion of the park and to fill water impoundments. In 1947, recycled water was pumped to Elk Glen Lake which was used as the sewage treatment plant reservoir. From there, recycled water was pumped to the reservoir on top of Strawberry Hill in order to fill Stow Lake and service the eastern portion of the park (Suen, 1966). In a report prepared in 1973, the volume of recycled water and well water was estimated to be approximately 0.72 and 2.0 million gallons per day (mgd; Mallick, 1973). Minor amounts of City water were also used for irrigation, particularly in the area of Lindley Meadows.

Recycled water use within the park continued until 1982 when new state regulations requiring tertiary treatment of wastewater compelled the SFRPD to discontinue recycled water use and rely solely on ground water and City water sources (JMM, 1992).

In October, 1991, the San Francisco Board of Supervisors passed two companion ordinances regarding recycled water use (Nos. 390-91, 391-91). These companion ordinances, known as the Recycled Water Use Ordinance, directed the San Francisco Water Department (SFWD) and the Department of Public Works (DPW) to prepare a coordinated, comprehensive citywide plan for the efficient expansion of the use of recycled water and ground water sources by all water consumers in San Francisco (City and County of San Francisco, 1991).

In response to the Recycled Water Use Ordinance, the City and County of San Francisco contracted James M. Montgomery, Consulting Engineers, Inc. (JMM) to prepare a Water Recycling Master Plan for San Francisco. This plan, which develops a comprehensive long-range plan for expanding the use of recycled water, was submitted to the City and County of San Francisco in October, 1992.

The Recycled Water Use Ordinance requires that any new landscaped area located within the boundaries of a recycled water use area shall be developed to use recycled water if it comprises an area of 10,000 square feet or more. Additionally, any existing irrigation systems located within the boundaries of a recycled water use area shall be converted for the use of recycled water if the irrigated site comprises an area of 10,000 square feet or more (City and County of San Francisco, 1991).

GGP, located within a recycled water use area, comprises 763 irrigated acres or approximately 33.2 million square feet. Therefore, GGP is a likely candidate for conversion to recycled water use. As described in Section 4.0, total irrigation water requirements have been estimated, using both direct and indirect techniques, to range from approximately 1.5 mgd to 1.75 mgd.

5.2 Regulatory Requirements

According to information provided in the Water Recycling Master Plan, the State of California Department of Health Services (DOHS) is responsible for the development of regulations and guidelines regarding water recycling and reuse within the state (JMM, 1992). Specific regulations pertaining to the use of recycled water for irrigation are addressed in the California Code of Regulations (CCR) Title 22. The level of treatment for recycled water required by Title 22 depends on the degree of human contact associated with its use. Golden Gate Park falls under the regulatory category of Irrigation of Areas with "High Risk of Public Exposure" (JMM, 1992). High public exposure includes the potential for accidental drinking of recycled water and the inhalation of aerosols. The existing regulations for the use of recycled water with high public exposure require the full Title 22 treatment: bio-oxidation, coagulation, clarification, filtration, and disinfection to limit coliforms to 2.2 MPN/100ml (JMM, 1992).

Regulations for the use of recycled water in non-restricted recreational impoundments, including Stow Lake in GGP, also require full Title 22 treatment (JMM, 1992). Other impoundments at GGP, where human contact is restricted, would not necessarily require tertiary treatment.

5.3 Vegetation

During the User Survey conducted for the Water Recycling Master Plan, SFRPD personnel expressed concern that recycled water may impact the ornamental vegetation in Golden Gate Park (JMM, 1992). Although salinity is the primary cause for concern regarding the use of recycled water for irrigation, the level of bicarbonate, sodium, boron and nitrogen may also be of concern.

An evaluation of the existing effluent water quality with respect to the user-based water quality requirements was completed for the Water Recycling Master Plan (JMM, 1992). Then, preliminary water quality criteria for irrigation of parks and golf courses were compiled by JMM and compared to the levels found in effluent water from the Southeast Water Pollution Control Plant (SEWPCP) and the Richmond-Sunset Water Pollution Control Plant (RSWPCP). Since the Oceanside Water Pollution Control Plant (OWPCP) is under construction until 1994, water quality projections were based on data from the RSWPCP.

Based on the preliminary water quality criteria for irrigation water, the SEWPCP effluent is presently unsuitable for irrigation because of unacceptable levels of salts, specifically chloride. However, effluent from the RSWPCP appears suitable for irrigation (JMM, 1992). The Water Recycling Master Plan reports that all the concentrations of the constituents of concern to be produced at the OWPCP are likely to be within the acceptable or marginal levels for irrigation.

One additional issue, regarding the suitability of RSWPCP effluent for sprinkler irrigation, was reported in the Master Plan. Although RSWPCP effluent is well into the marginal range for sodium and chloride concentrations, it is nearly double the levels deemed acceptable for sprinkler irrigation (JMM, 1992). Due to the possibility of sodium and chloride accumulation and absorption onto the leaves, the growth of sensitive plants may be adversely affected if RSWPCP effluent is applied with sprinkler irrigation (JMM, 1992). The Water Recycling Master Plan indicated that potential problems may be avoided by surface irrigation of sensitive plants.

Figure 5-1 is a map of GGP showing suspected sensitivities of various vegetation types to high salinities associated with the use of recycled water. This map was constructed using various guidelines for the use of recycled water on landscaping and on conversations with Mr. Jim Cooney of SFRPD, Urban Forestry and Turf Management (November 23, 1992). The horticultural attractions of primary concern in GGP include:

The Rose Garden
The Arboretum
The Conservatory and Conservatory Valley
Rhododendron gardens
Redwood trees
Oak trees
Tree ferns
Cherry and plum trees
GGP Golf Course greens
The Lawn Bowling greens

The real impact of future recycled water on GGP vegetation is not known and will depend on a variety of factors such as the type and age of plant, the quality of the recycled water, the soil type, irrigation method, and drainage conditions. Although recycled water was used in the past for irrigation, it was substantially diluted with well water, thus its impact on GGP vegetation cannot be assessed.

To assess the impact of recycled water on various vegetation types, it is recommended that bench tests, using recycled water alone, as well as mixtures blended with well water, be conducted on vegetation of concern prior to implementing plans to modify existing irrigation systems or constructing new irrigation systems to accommodate the use of recycled water.

5.4 Water Impoundments

During the User Survey, SFRPD personnel expressed concern over the storage of recycled water in the GGP lakes because the nutrient levels (nitrogen and phosphorus) typically present in recycled water would promote algae growth in the lakes (JMM, 1992). SFRPD reported that, based on past experiences with recycled water, algae could potentially plug the irrigation devices and may be a visual eyesore [illegible] park visitors (JMM, 1992).

Previous experience at Elk Glen Lake, which was used as a reservoir for recycled water, showed that both eutrophication (algae growth) and the formation of foams was common (Suen, 1966).

Based on the observations above, the Water Recycling Master Plan did not recommend recharge of GGP lakes using recycled water.

5.5 Land Use

Regulations regarding the use of recycled water for irrigation in the vicinity of potable water supply wells are set forth by the California Code of Regulations (CCR) Title 22. These regulations stipulate that recycled water used for irrigation must be at least 100 feet away from an irrigation well, and 500 feet of any well used for potable water supply. Therefore, in the event that recycled water is used for irrigation in GGP, its use must be restricted accordingly.

5.6 Water Supply Distribution

The Water Recycling Master Plan presents various alternatives for the construction of tertiary treatment plants and subsequent distribution of recycled water to potential users. For the west side of San Francisco, treatment plant locations include the Armory, the Richmond-Sunset WPCP, San Francisco State University, The Presidio, and Balboa Reservoir. From the selected treatment plant, recycled water would be piped to a storage facility. Storage facility locations suggested in the Water Recycling Master Plan include the Laguna Honda Reservoir and the Balboa Reservoir. From the selected storage facility, recycled water could either be distributed through existing San Francisco Fire Department (SFFD) high-pressure auxiliary water supply system (AWSS) or through new pipelines.

An AWSS line currently runs through GGP between Lincoln and Fulton Avenues in the vicinity of 9th and 10th Avenues (See Figure 4-1). If the AWSS system is the selected distribution system, then recycled water could be supplied to GGP through this line. From this central pipeline, storage for distribution throughout the park will be needed. Although water impoundments have previously been used to store recycled water, this option is not considered due to expected eutrophication.

Potential reservoir sites could include 1) an expansion of the reservoir at North Mill well, 2) a buried water tank at the South Mill well, and/or 3) a buried water tank north of McLaren Lodge (Personal communication, Ms. Deborah Learner, March 8, 1993). From these locations, recycled water could be distributed through existing or modified irrigation lines.

Recycled water distribution may be selective throughout GGP. As discussed above, some ornamental plants may not respond well to recycled water, particularly if spray irrigation is continued at the park. Other constraints, such as drainage into water impoundments, may exist. A future irrigation system may be composed of dual, or even triple piping, in some areas in order to best utilize all water resources within the park.

6.0 GEOLOGIC AND SEISMIC HAZARDS

Geologic hazards within GGP do not appear to be a significant problem. Localized erosion and earthquake-related hazards typical of the Bay Area are the principal hazards of concern.

6.1 Erosion and Slope Stability

Soil erosion in GGP is minor and is generally confined to limited areas. The abundant vegetation of GGP assists in the prevention of soil erosion. GGP personnel indicated that some areas of the park suffer from soil erosion problems. Mr. John Huttinger of the SFRPD reported that erosional areas are primarily limited to the Buffalo Paddock, various bike and horse trails, and some portions of Strawberry Hill (Personal communication, Mr. Huttinger, SFRPD, November 25, 1992).

Slopes in GGP are generally not very steep, are underlain by well drained sandy soils, are well vegetated, and are not prone to slope stability problems, such as landslides and ravelling. Interviews with GGP personnel indicated that slope stability issues have not been a historical problem within the park (Personal communication, Mr. John Huttinger, SFRPD, November 25, 1992). Due to the nature of the dune sands that underlie a great portion of GGP, slope stability problems that may arise in the future will most likely be only small, localized slumps or debris flows.

Hazards related to seismicity generally include ground shaking, liquefaction, lateral spreading, differential settlement, densification, ground rupture along fault traces, and inundation by encroaching waves (tsunami).

6.2 Ground Shaking

The potential for strong ground shaking from earthquakes generated on active faults in the region is a significant seismic hazard throughout the Bay Area and in GGP. Ground shaking intensities would vary depending on the magnitude of the earthquake, the distance of GGP from the causative fault, and the type of materials underlying the suspect portion of the park. During the lifetime of the park structures, GGP is likely to be subjected to at least one moderate to severe earthquake that would cause strong ground shaking. The effect of strong shaking on structures depends primarily on the design and structural conditions of the structures.

6.3 Liquefaction

Liquefaction is the sudden temporary loss of shear strength in saturated, loose to medium dense, relatively clay-free sands and silts. It occurs when rapid compaction during seismically induced ground shaking causes pore water pressure to increase to a point that it equals the confining pressure of the soil. Liquefaction can cause serious building foundation failures due to the loss of foundation bearing strength. The potential for liquefaction depends on the duration and intensity of earthquake shaking, particle size distribution of the soil, density of the soil, and elevation of the groundwater. Liquefaction can also be accompanied by ground cracking and differential settlement.

As previously noted, GGP is underlain by dune sand and the Colma Formation. The dune sand is clean, well sorted, fine to medium sand and the Colma Formation is unconsolidated fine to medium sand with a small to moderate amounts of silt and clay (Yates, 1990). These sands, if saturated, may be liquefiable if subjected to moderate to severe ground shaking. The effective depth limits of the mechanisms of liquefaction have not been determined. In general, however, depths shallower than 30 to 40 feet may be considered at risk for liquefaction. Based on the approximate depths to groundwater in GGP, portions of the park that may be at risk for liquefaction are found west of North Lake. During a wet winter, the groundwater table may be higher and could result in liquefaction effects impacting a larger area.

6.4 Lateral Spreading

Lateral spreading results from predominantly horizontal displacement of alluvial material toward a slope or stream cut bank during strong ground shaking. This movement is due to ground failure, most likely liquefaction, of one or more layers of alluvium exposed in the open slope face. Lateral spreading can also be accompanied by shear and tensile cracking of the ground surface. Lateral spreading can also occur on nearly flat-lying terrain where horizontal displacement takes place toward an unsupported slope face such as a steep stream bank.

The potential for lateral spreading is considered to be low for the eastern and central portions of GGP which were judged to be less susceptible to liquefaction due to groundwater levels deeper than 40 feet. Steep, unsupported slopes found west of North Lake, where groundwater is shallow, may be at risk of lateral spreading during strong to severe seismic shaking. During a wet winter, the groundwater table may be higher and could result in lateral spreading occurring in other areas of GGP.

6.5 Differential Settlement and Densification

Earthquake shaking can produce compaction and densification of dry, uniformly graded, granular material that is loose in consistency. The amount of compaction across an area can vary due to differences in soil types, producing differential settlement. Because the soils in GGP are primarily unconsolidated fine to medium sands, the risk of densification and differential settlement is considered to be moderate to high. Settlement can impact inadequately designed or improperly constructed structure foundations. Assessment of specific conditions underlying individual sites should occur on a site-by-site basis.

6.6 Ground Rupture

Based on current and available geologic data, there are no known active or potentially active faults within GGP, nor is any portion of the park located within a fault-rupture hazard zone delineated by the Alquist-Priolo Special Studies Zones Act. The City College fault crosses GGP approximately 1 mile from the coast, between the Elk Glen well and the Windmill wells (USGS, 1990). This fault is not considered to be active by the CDMG. Therefore, the risk of fault rupture of the ground surface is considered to be very low.

6.7 Tsunami Inundation

Tsunamis (seismic sea waves) are long period waves that are caused by underwater disturbances (landslides), volcanic eruptions, or distant seismic events. Areas that are highly susceptible to tsunami inundation tend to be located in low lying coastal areas such as tidal flats, marshlands, and former bay margins that have been artificially filled but are still at or below sea level. In 1972, a determination of the areas surrounding San Francisco Bay that might be inundated was calculated based on an assumed tsunami run-up of 20 feet at the Golden Gate (Ritter and Dupre, 1972). Ocean Beach, the Great Highway, and portions of GGP immediately adjacent to the Great Highway may be at risk of inundation by a tsunami. If a tsunami were to occur at maximum high tide, the effects of tsunami inundation could impact a larger area, to an elevation approximately 20 feet higher than higher high tide.

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TABLE 2-1

KNOWN ACTIVE AND POTENTIALLY ACTIVE FAULTS IN THE SITE VICINITY

Fault	Maximum Credible Earthquake (1)	Average Values of Maximum Estimated Bedrock Acceleration (g) (3)	Site Distance From Fault (miles)
San Andreas	8.3	0.60	4 SW
Hayward	7.5	0.34	15 E
Calaveras	6.0	0.10	25 E
Rodgers Creek	7.0 (2)	0.15	30 N
Green Valley	6.6	0.10	32 NE
Concord	5.4	0.04	27 NE

1. Wesson, et al, 1975
2. Budding, et al, 1991
3. Seed and Idriss, 1982

TABLE 3-1

GENERAL MINERAL ANALYSIS FOR GOLDEN GATE PARK WELLS, 1988

WELL NAME	DATE	Specific Conductance (µS/cm)	pH (Standard units)	Temperature, water (°C)	Calcium dissolved	Magnesium, dissolved	Sodium, dissolved	Potassium, dissolved	Bicarbonate, (as CO_3)	Carbonate, (as $CaCO_3$)	Alkalinity, (as $CaCO_3$)	Hardness[1] dissolved	Sulfate, dissolved	Chloride, dissolved	Fluoride, dissolved	Bromide, dissolved	Silica, dissolved	Nitrogen NO_2+NO_3, dissolved (as N)
Northwest Windmill	3/2/88 5/4/88	385 371	7.9 8	- 18.5	19 19	23 22	26 26	1.3 1.4	146 152	0 0	120 125	142 138	8.8 8.2	38 38	0.20 0.10	0.11 0.12	44 43	2.4 2.5
Northeast Windmill	3/2/88	660	7.5	-	33	42	34	1.9	258	0	211	254	48	47	0.20	0.16	37	-
South Windmill	3/2/88 5/4/88	420 467	7.7 7.8	- 17.5	22 25	25 29	23 26	1.2 1.7	142 166	0 0	116 136	157 181	15 28	35 39	0.10 0.10	0.11 0.15	41 39	6.5 7.9
Elk Glen	3/2/88 5/4/88	529 566	7.7 7.9	17.5 17.0	31 34	33 37	26 26	1.1 1.3	154 174	0 0	126 143	213 237	29 41	41 46	0.20 0.10	0.16 0.24	43 42	12 14
Arboretum No. 5	3/2/8[illegible] 5/4/[illegible]	566 572	7.2 7.3	16.5 16.0	32 31	41 40	26 26	2.4 2.6	196 194	0 0	161 159	248 241	33 38	30 28	0.10 0.10	0.24 0.25	38 36	15 17
Alvord	3/2/88 5/4/88	625 620	7.8 7.9	17.5 17.0	30 33	32 34	47 50	1.1 1.1	214 216	0 0	175 177	206 222	30 33	59 56	0.20 0.20	0.30 0.31	47 49	- 9.7

Taken from USGS, 1990; data presented in mg/l unless otherwise indicated

[1] Calculated by JMM, August 1991

TABLE 4-1

GROUNDWATER PUMPAGE IN GOLDEN GATE PARK
1989 WATER YEAR (M/gal)[1]

SITE	1988			1989								
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Alvord	3.2	3.4	2.7	2.8	2.7	3.2	3.0	2.6	2.5	2.4	2.7	2.9
Arboretum No. 4	2.5	0.0	0.0	0.0	0.2	0.8	1.5	2.5	3.8	3.6	3.4	2.8
Arboretum No. 5	1.4	0.2	0.1	0.0	0.0	0.4	0.7	1.2	1.6	1.8	1.7	1.4
Elk Glen	20.3	26.1	24.9	24.9	19.8	21.2	24.0	40.6	32.1	33.4	29.0	22.9
NW Mill (NN)	4.2	0.6	0.0	1.2	0.3	1.3	2.4	2.5	4.6	3.0	2.6	1.8
NE Mill (NS)	3.0	0.4	0.1	0.9	0.2	1.0	1.8	1.9	3.4	2.2	1.8	1.4
S Mill	0.0	0.0	0.0	0.0	1.5	3.5	2.8	3.1	3.7	1.7	0.5	0

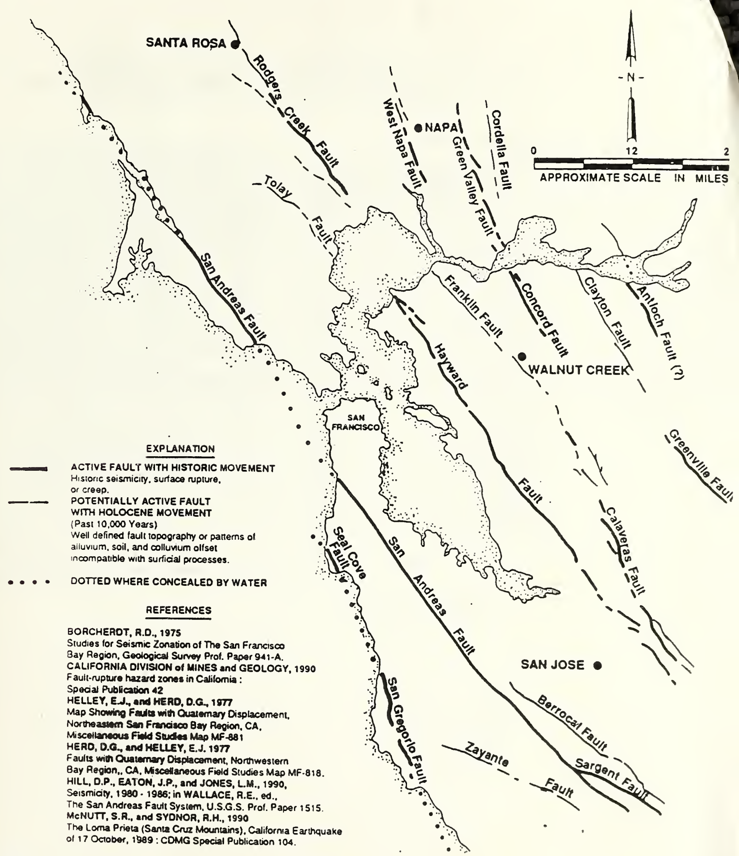
1. From USGS date files, 1990
2. Converts to 1363 acre-feet

TABLE 4-2

CITY WATER USE FOR IRRIGATION IN GOLDEN GATE PARK
1988 WATER YEAR

SFWD SERVICE CONNECTION LOCATION	RECORD CHANGE DATE	BILLING UNITS USED			ANNUAL USE	
		10-1-87 TO CHANGE DATE	CHANGE DATE TO 9-30-88	TOTAL	M/GAL[1]	ACRE-FT[2]
100 Transverse	4/20/88	37,704	31,887	69,591	52.0	159.7
300 Lincoln	3/19/88	6,533	5,420	11,953	8.9	27.4
850 Lincoln	3/19/88	3,269	3,468	6,737	5.0	15.5
4644 Lincoln	4/20/88	114	105.8	220	0.2	0.5
GGP	3/20/88	1,320	3,708	5,028	3.8	11.5
1500 Oak St.	4/23/88	3,103	6,533	8,636	8.9	19.8
1898 Oak St.	2/22/88	50.5	172.8	223	0.2	0.5
1998 Oak St.	4/20/88	1,712	2,991	4,703	3.5	10.8
2301 Fulton	4/23/88	1,670	1,377	3,047	2.3	7.0
3801 Fulton	4/20/88	9,040	11,300	20,340	15.2	46.7
6301 Fulton	2/19/88	0	27,659	27,659	20.7	63.5
					118.3	362.9

1. 1 billing unit = 748 gallons
2. 1 acre-ft = 0.3258 M/gal



EXPLANATION

━━ ACTIVE FAULT WITH HISTORIC MOVEMENT
Historic seismicity, surface rupture, or creep.

— — POTENTIALLY ACTIVE FAULT WITH HOLOCENE MOVEMENT
(Past 10,000 Years)
Well defined fault topography or patterns of alluvium, soil, and colluvium offset incompatible with surficial processes.

• • • • DOTTED WHERE CONCEALED BY WATER

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9/91

Geo/Resource Consultants, Inc.
GEOLOGISTS / ENGINEERS / ENVIRONMENTAL SCIENTISTS
505 BEACH STREET, SAN FRANCISCO, CALIFORNIA 94133

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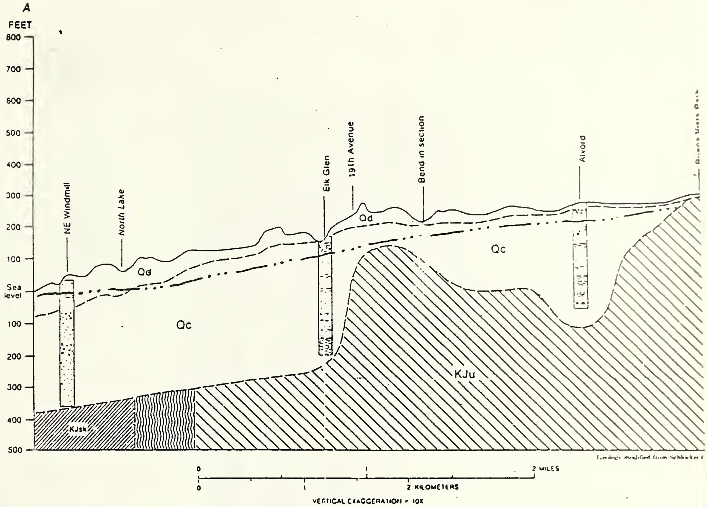
MAJOR HISTORIC ACTIVE
and
POTENTIALLY - ACTIVE FAULTS
in the
SAN FRANCISCO BAY AREA

FIGURE
2-3



Geology modified from Schlocker

EXPLANATION

QUATERNARY	Pleistocene and Holocene	Qd	DUNE SAND - Clean, well-sorted fine to medium sand
		Qc	COLMA FORMATION - Unconsolidated fine to medium sand with small to moderate amounts of silt and clay
LATE JURASSIC AND CRETACEOUS		▥	CITY COLLEGE SHEAR ZONE - Sheared rocks of the Franciscan Complex and Great Valley Sequence
		KJu	FRANCISCAN COMPLEX - Consolidated and fractured sandstone, shale, chert, greenstone, and serpentine
		KJsk	GREAT VALLEY SEQUENCE - Consolidated, fractured sandstone generally containing more than 2 percent potassium feldspar
		— —	CONTACT - Approximately located
		Alvord	WELL IDENTIFIER
		——— • • • —	WATER LEVEL - Based on USGS, 1990

BOREHOLE LITHOLOGY

- ☐ Sand
- ▤ Silt
- ▤ Clay
- ⁘ Gravel

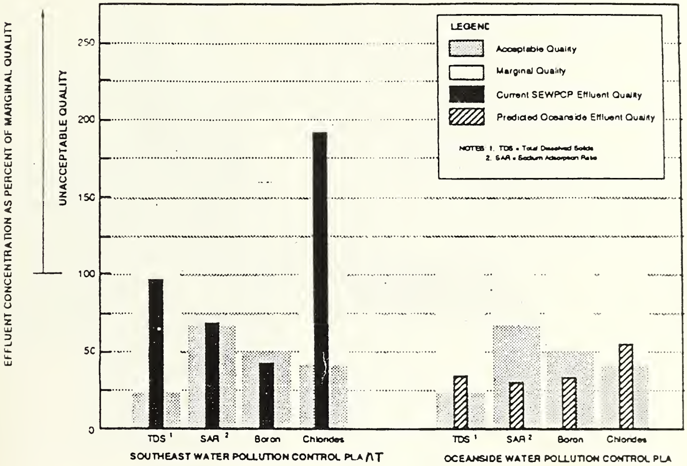
REFERENCE : USGS, 1990

Geo/ Resource Consultants, Inc.
GEOLOGISTS / ENGINEERS / ENVIRONMENTAL SCIENTISTS
505 BEACH STREET, SAN FRANCISCO, CALIFORNIA 94133

Job No. 1762-000 Appr. ________ Date 3/22/93

HYDROGEOLOGIC CROSS-SECTION THROUGH EXISTING WELLS IN GOLDEN GATE PARK

FI



PREDICTED SUITABLITY OF RECYCLED WATER SOURCES FOR IRRIGATION USES

Figure 5-1

Reference JMM, October, 1992

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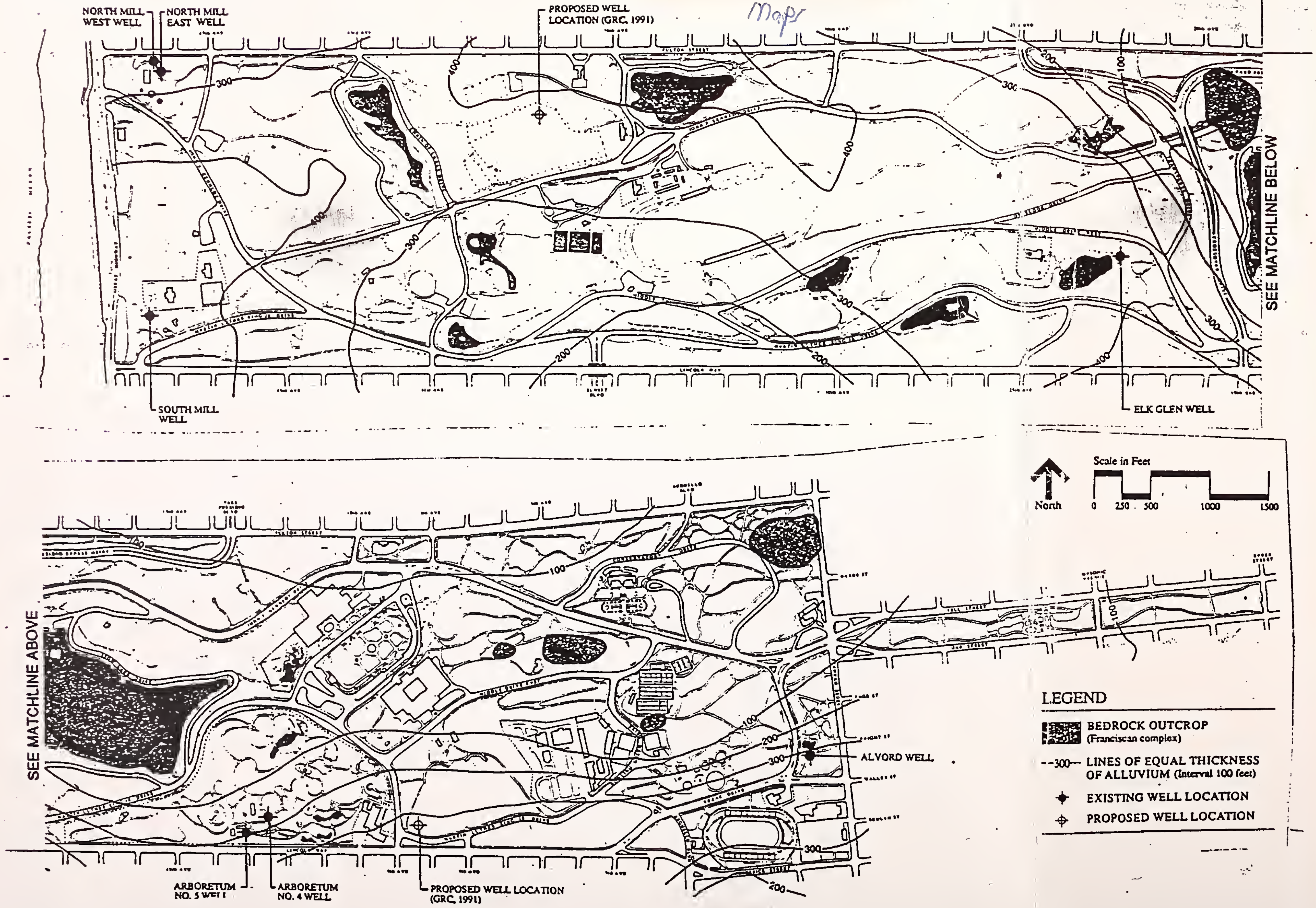
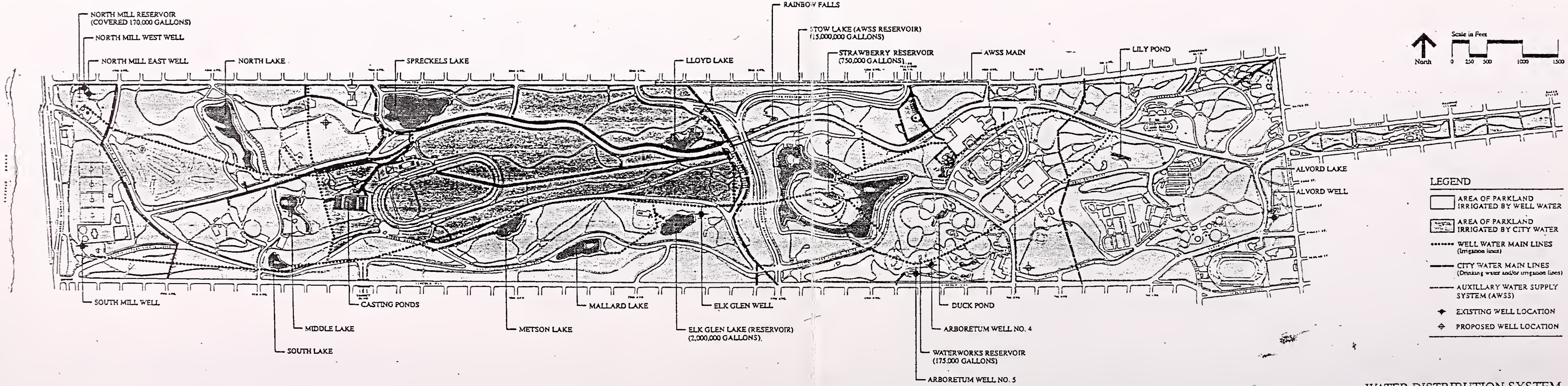
C

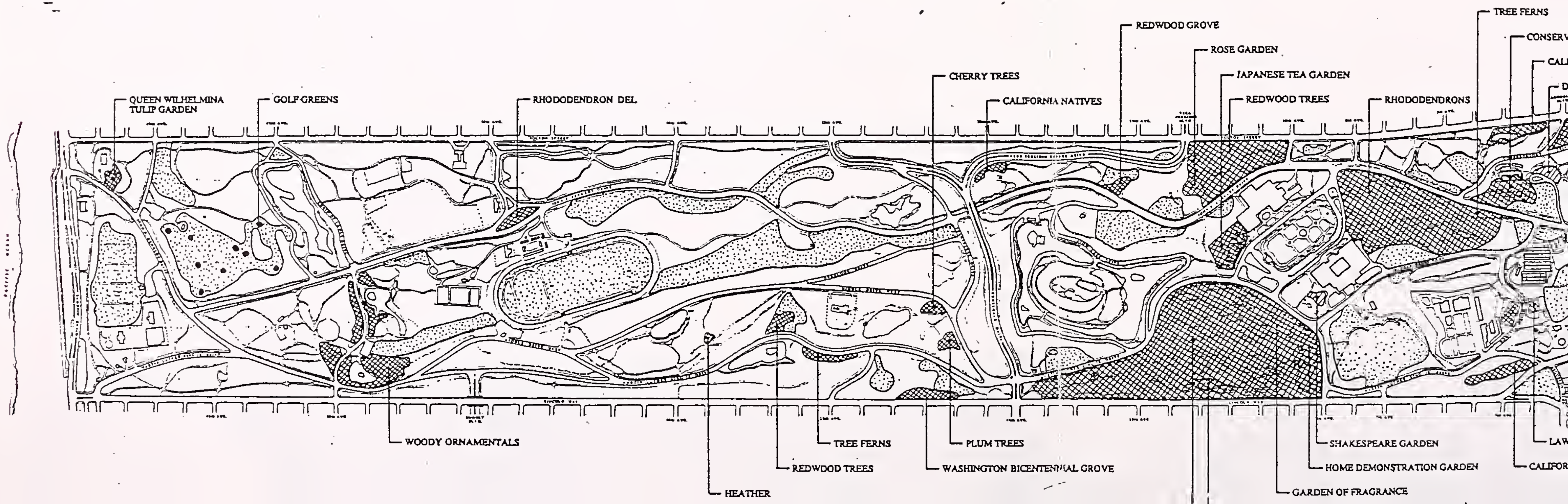
Maps

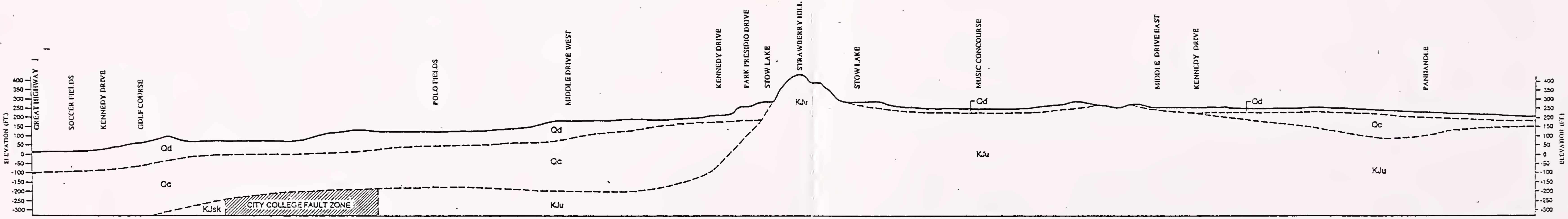


ALLUVIAL THICKNESS AND WELL LOCATIONS


NORTH MILL RESERVOIR (COVERED 170,000 GALLONS)
NORTH MILL WEST WELL
NORTH MILL EAST WELL
NORTH LAKE
SPRECKELS LAKE
LLOYD LAKE
RAINBOW FALLS
STOW LAKE (AWSS RESERVOIR) (15,000,000 GALLONS)
STRAWBERRY RESERVOIR (750,000 GALLONS)
AWSS MAIN
LILY POND
North
Scale in Feet
0
250
500
1000
1500
ALVORD LAKE
ALVORD WELL
SOUTH MILL WELL
CASTING PONDS
MIDDLE LAKE
SOUTH LAKE
METSON LAKE
MALLARD LAKE
ELK GLEN WELL
ELK GLEN LAKE (RESERVOIR) (2,000,000 GALLONS)
DUCK POND
ARBORETUM WELL NO. 4
WATERWORKS RESERVOIR (175,000 GALLONS)
ARBORETUM WELL NO. 5
LEGEND
AREA OF PARKLAND IRRIGATED BY WELL WATER
AREA OF PARKLAND IRRIGATED BY CITY WATER
WELL WATER MAIN LINES (Irrigation lines)
CITY WATER MAIN LINES (Drinking water and/or irrigation lines)
AUXILLARY WATER SUPPLY SYSTEM (AWSS)
EXISTING WELL LOCATION
PROPOSED WELL LOCATION

WATER DISTRIBUTION SYSTEM


QUEEN WILHELMINA TULIP GARDEN
GOLF GREENS
RHODODENDRON DEL
CHERRY TREES
CALIFORNIA NATIVES
REDWOOD GROVE
ROSE GARDEN
JAPANESE TEA GARDEN
REDWOOD TREES
RHODODENDRONS
TREE FERNS
CONSERV
CAL
D
WOODY ORNAMENTALS
HEATHER
REDWOOD TREES
TREE FERNS
WASHINGTON BICENTENNIAL GROVE
PLUM TREES
GARDEN OF FRAGRANCE
HOME DEMONSTRATION GARDEN
SHAKESPEARE GARDEN
LAW
CALIFOR

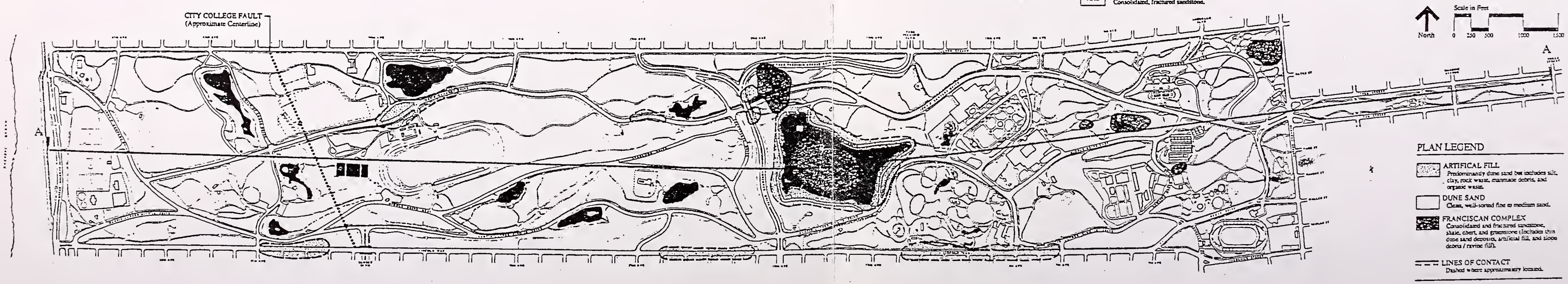


SECTION A-A'

SCALE:
HORIZONTAL: 1" = 500'
VERTICAL: 1" = 200'

SECTION LEGEND

Qd	**DUNE SAND** Clean, well-sorted fine to medium sand.
Qc	**COLMA FORMATION** Unconsolidated fine to medium sand with small to moderate amounts of silt and clay.
KJu	**FRANCISCAN COMPLEX** Consolidated and fractured sandstone, shale, chert, and greenstone (Includes thin dune sand deposits, artificial fill, slope debris / ravine fill).
KJsk	**GREAT VALLEY SEQUENCE** Consolidated, fractured sandstone.
▨	**CITY COLLEGE FAULT ZONE** Sheared rocks of the Franciscan Complex and Great Valley Sequence.



PLAN LEGEND

▒	**ARTIFICAL FILL** Predominantly dune sand but includes silt, clay, rock waste, manmade debris, and organic waste.
☐	**DUNE SAND** Clean, well-sorted fine to medium sand.
▓	**FRANCISCAN COMPLEX** Consolidated and fractured sandstone, shale, chert, and greenstone (Includes thin dune sand deposits, artificial fill, and slope debris / ravine fill).
— —	**LINES OF CONTACT** Dashed where approximately located.

GEOLOGY